

Save Money on Seismic Retrofits with Metallic Dampers

Business Issue

Earthquakes occur on a regular basis in the western United States. Since the 1989 Loma Prieta California earthquake, the California Department of Transportation has launched a comprehensive retrofit program for deficient bridges in the entire state, and several trillions have been spent over the years to retrofit their transportation infrastructure. In the Central United States, the occurrence of seismic activity is infrequent, and such a system wide retrofit approach in Missouri would be overkill. However, Missouri has many bridges that were built before seismic design guidelines were accepted as standard specifications. Their performance level is astoundingly low according to modern seismic design guidelines. To provide safe bridges at the best value, MoDOT needs to find economical solutions for seismic retrofit of existing highway bridges.

Background

The first version of the seismic design criteria was available in 1975 from the American Association of State Highway and Transportation Officials (AASHTO). In 1981 AASHTO approved the Seismic Design Guidelines for Highway Bridges, which was published by the Federal Highway Administration. This was accepted as the standard specification throughout the United States for bridge design. Prior to these design codes little seismic evaluation was performed, particularly in the Central and Eastern United States, and as a result there are many existing bridges that are inadequately prepared for a seismic event. On the other hand, no strong earthquake has struck this area since 1811-1812 though small earthquakes occur on a regular basis. Therefore, it is imperative to develop an economical solution for the seismic retrofit of critical existing highway bridges in southeast Missouri, which are within infrequent occurrence seismic zones in the Central and Eastern United States. Due to the regional seismic activity, a cost-effective retrofit strategy in Missouri would be to mainly upgrade critical bridges against safety-related design earthquakes described in the bridge specifications. Damages of the retrofitted bridges or retrofitting devices are acceptable under less severe earthquakes.

Approach

Metallic dampers mainly consist of low carbon steel rods that can be installed between the superstructure (deck) and the substructure (bent cap) of a steel-girder bridge. They function as a fuse member in the bridge system. As the intensity of horizontal earthquake motions increases, the dampers are subjected to shear deformation. These dampers eventually undergo extensive inelastic deformation, thus dissipating most of seismic energy that would, prior to retrofitting, be stored in structural members in the form of strain energy and cause structural damages.

Previous studies ^[1] indicated that metallic dampers consisting of low carbon steel prismatic rods can be used to mitigate the seismic responses of bridge structures. As a continuation of the previous studies, MoDOT has recently completed a new study ^[2] to address several issues related to the implementation of metallic dampers in steel-girder bridges with rocker bearings. Specifically, the objectives of this study were:

¹ Chen, G. D., Mu, H. M., Bothe, E. R. (2001). *Metallic Dampers for Seismic Design and Retrofit of Bridges*. Report RDT 01-005, Missouri Department of Transportation, Jefferson City, MO, USA.

- Further improve the performance of dampers with tapered rods,
- Establish design equations for the damping property of tapered metallic dampers,
- Validate the previously-proposed design procedure for bridge systems including metallic dampers,
- Study the effect of transverse beams, used to connect dampers from capbeam to steel girders, on the damping properties of dampers, and
- Develop a hysteresis model of the load carrying capacity of rocker bearings.

In addition to the above objectives, the previously proposed step-by-step procedure for the seismic retrofit of highway bridges was examined and applied into the retrofit design of a three-span continuous steel-girder bridge in southeast Missouri.

Conclusions and Recommendations

- Low carbon steels, Hot Rolled AISI/SAE1018, are an economic yet effective solution for the seismic retrofit of highway bridges in low occurrence seismic regions. These readily available materials have a yielding stress of 32 ksi.
- The effective stiffness of tapered steel rods decreases steadily as the applied displacement of harmonic loading increases. However, the damping ratio of the tapered rods, independent of loading frequency and specimen size, increases rapidly at small displacement and approaches to a value of 0.35~0.40 at displacement of over 1.8 inches.
- At a high displacement of 2.4" or less, steel rods can survive over 100 cycles of loading without degrading their load-displacement hysteresis loops. As illustrated in Figures 1 and 2, they fracture at the mid-height of the cantilevered rods when welded to their base plate well. Under irregular loads, the fatigue strength of steel rods depends upon the sequence of loading; the commonly used Miner's rule could underestimate the strength of rods by 45 percent.

- For the Old St. Francis River Bridge, it is recommended that eight sets of five-rod dampers be installed on each of its two intermediate bents to make the three-span con-

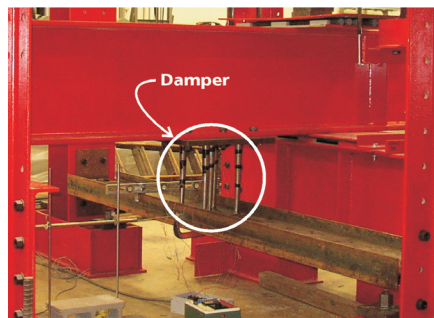


Fig. 1 Test Setup of a Full-Scale Damper

tinuous steel-girder bridge seismic resistant. The validation test of one five-rod damper together with its supporting structural components, as shown in Figure 1, proves that all five rods fail one by one near the highest stress loca-

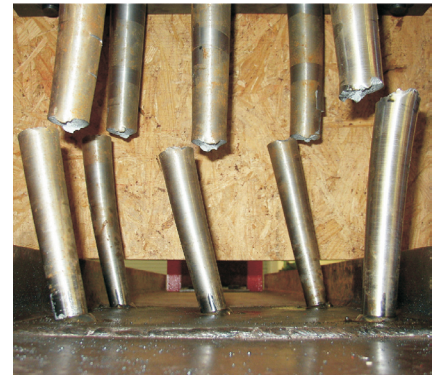


Fig. 2 Failure Mode of the Damper

tion, resulting in a progressive failure mode that is desirable for earthquake applications, as illustrated in Figure 2. The performance of the damper and other structural components as a system is quite satisfactory.

- The seismic behavior of Type D expansion bearings can be simulated with a bi-linear model. The model parameters have been determined from the test results of 16 bearings retrieved from two decommissioned bridges. Test results from the earlier study also indicated that Type D bearings can accommodate an ultimate horizontal displacement of over 5 inches before they become unstable.

² Chen, G. D., Mu, H. M., Bothe, E. R. (2005). Behavior and Fatigue Properties of Metallic Dampers for Seismic Retrofit of Highway Bridges. Report RDT 05-007, Missouri Department of Transportation, Jefferson City, MO, USA.

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